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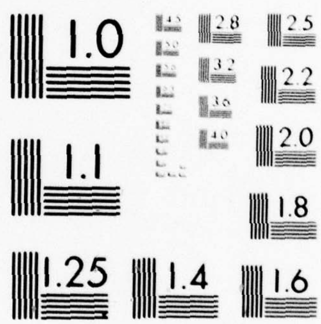
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# PROBLEM SUMMARY FOR SF 11-121-100/8132

# (NUWC PROBLEM E1-11)

# FOR THE PERIOD 1 JANUARY 1968 - 1 JULY 1968


10 by C. S. Stradling

San Diego, California




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# ILLUSTRATIONS



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# 1. INTRODUCTION

This report summarizes NAVSHIPS Problem Number SF 11-121-100/8132 (NUWC No. E1-11) for the period 1 January 1968 through 1 July 1968. It is intended to supplement the semi-annual program book for Mr. G. E. Miller (SHIPS 00V1C) and Mr. C. D. Smith (SHIPS 00V1).

Only limited distribution is contemplated.

## 1.1 OBJECTIVE

To determine properties of acoustic signals, signal processing, and display techniques, and terminal decision procedures which can be used effectively to detect and classify active sonar contacts. To provide in technical reports or as system design assistance, the basis for improved detection and classification techniques in operational systems. Provide technical assistance to NAVSHIPS and its contractors in program planning and research and development projects in above areas.

## 1.2 APPROACH

Improvements in sonar detection and classification require search for better signal information and for ways to make more effective use of known information. Physical analysis and quantitative tests of raw and processed sonar signals from operational and experimental equipments are used to identify signal variables which show promise for detection and classification discrimination. Signal processing, computer simulation and electronic display techniques, together with supporting theoretical concepts of information processing, communication theory, and decision theory are applied to signal waveforms to establish the effectiveness and design requirements of automatic and semi-automatic detection and classification systems. Results of these applied research and exploratory development efforts are split-off into systems development as practical techniques are proven.

## 1.3 BACKGROUND AND STATUS

Previous classification work was centered primarily on two basic approaches to problem solution. The first approach was concerned with special purpose measurement equipments as characterized by MONOPPLER, ASPECT, and others. The second approach dealt with pattern recognition techniques and resulted in such systems as HHIP, MITEC, and TRESI being

designed and tested for use with contemporary scanning sonars. The advent of more sophisticated measurement extraction techniques, advanced theoretical models of decision systems and a new generation of long range sonar systems called for a reorientation to a third approach, referred to as the analytical-experimental approach.

The analytical-experimental approach can best be described as the application of statistical communication theory to the sonar detection and classification problem. It is concerned with describing, in an analytical manner, the sonar communication channel in order to make use of all available a priori information for classification, and in confirming the hypothesized channel by means of experimentation with real-world data. Advantage is being taken of ideas advanced in the last five years in the areas of statistical estimation and decision theory. Some of these theories have been unified into a set of techniques testable against real-world data. While a data base representative of the future sonar systems problem is being accumulated, SQS-23/PAIR data and simulated data is being used for preliminary experimentation with theoretical models of classification channel components.

Existing efforts include four main areas; applied research, data collection, facilities and consultation and auxiliary tasks. Within applied research, efforts include: a mathematical study of transmitted signals; methods for accurately locating echoes in ambient and reverberation noise backgrounds for CW and FM transmissions; the application of filtering techniques for estimating target parameters of range, range-rate, bearing and bearing-rate; a mathematical study of optimum classification principles for deterministic reflected and/or radiated target signals; operational considerations and their effect on classification with long range sonar systems; mathematical and experimental studies concerned with linear, time-varying, random target models. This work in applied research will permit a logical advance in and a rapid evaluation of receiver designs for classification purposes. The ASDACS system, to become operational in early Fiscal Year 1969, will support the above types of studies, and, together with the effort in data collection, will provide a strong relationship between exploratory development and the Navy's operational sonar systems.

# 2. AREAS OF INVESTIGATION

## 2.1 APPLIED RESEARCH

### 2.1.1 OPERATIONAL CONSIDERATIONS:

Olson[1] outlines an operational model of the active sonar classification problem. This reference does not consider all types of encounters, but it considers the very dangerous case of a well-defined, shallow thermocline resulting in below-layer detection ranges of 3000 yds or less. The effects of weapon ranges and contact times with possible submarine evasive tactics will require rapid classification. Doppler alone cannot provide as reliable a clue as size and shape. While sonars and classification techniques can use these clues at short ranges, the problem of short-term, longer-range contacts requires a different approach. This case arises when a periscope or passive sonar operation requires the submarine to come above the layer into the surface channel. The ranges for this type of contact are predicted as 10-24 kyds for time durations of approximately two minutes. At these ranges, familiar techniques for classifying by size and shape, such as SSI displays, profiling with high frequency, short-pulse sonars, or even Starlite, cannot provide significant classification capability. The long range, longer term contact, on the other hand, can often be classified by track information.

As a consequence of our current knowledge of classification (short-range), we are investigating the feasibility of converting the long-range, short-term contact to a short-range problem—which we hope proves easier to implement. The surface ship can employ a sonar designed for close-in classification employing either techniques similar to mine-hunting or using other techniques (such as Starlite).

The longer-range contact will be changed to a short-range contact by moving a platform close to the contact. The platform should be reasonably safe from torpedo attack and capable of closing the contact very quickly—as location information will not continue if the target goes below a well-defined layer. Several candidate approaches will receive

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1. D. G. Olson, "Operational and Tactical Considerations of Active Sonar Classification (U)," *Proceedings of Naval Ships Systems Command Symposium on Active Sonar Classification*, October 1967, (CONFIDENTIAL).

consideration as to feasibility. These approaches will be designated as DICLAS–Dispatched Classification Systems. A short list with some of the major considerations of each approach follows:

### 2.1.1.1 SHIP-LAUNCHED ACTIVE SONOBUOYS

Method of Delivery: Gun-fired or rocket-launched. Work with CLASP by NOTS[2] has proven the feasibility of launching a passive sonobuoy from a 5"38 deck gun and receiving the telemetered information at the ship. The MK 114 fire control system receives both sonar and radar inputs and controls the guns as well as the ASROC launcher. In this manner, a pattern over the contact or a pattern slightly offset can be rapidly delivered.

Classification Technique Proposed: The Starlite technique seems the best approach at this time. Studies as to optimum buoy placement to cover a wide range of submarine aspect angles, expected sonobuoy frequencies, signal waveforms and the ranges for underwater coverage will largely determine the feasibility. The ranges for buoy-ship telemetry will probably determine the maximum range of the system from the ship. As an example, line of sight ranges for various observation (antenna heights) are given for reference:

| | |
|---|---|
| 4 ft. height– | 2.3 mi. range |
| 50 ft. | – 8.1 mi. |
| 100 ft. | –11.5 mi. |

Additional Comments: Operationally, the geometry of the buoys relative to each other must be fairly well-known to provide the best performance. Computer techniques for interpreting buoy geometry and processing the telemetered information for classification decisions must be developed. Current active sonobuoys and those under development can provide initial inputs for the feasibility studies. If the technique (classification with active buoys) proves reliable, the problems of packaging for launch from surface ships and possibly submarines can be pursued.

2. J. R. Olmstead, J. W. Taylor, "Investigation of a Ship-Projected Sonobuoy System to Aid Target Classification (CLASP)," *24th Navy Symposium on Underwater Acoustics*, 29 November - 1 December 1966 (CONFIDENTIAL).

### 2.1.1.2 HELICOPTERS, VS/VP AIRCRAFT–ACTIVE SONOBUOYS

Comments: Essentially, the same comments apply for the use of Starlite with active sonobuoys. However, the height of the platforms will permit much greater telemetry-ranges. VS/VP aircraft can then plant large fields of CASS (Command Activated Sonobuoys) to detect and classify the slow-moving submarine in the van of a convoy. The use of sonobuoys from helicopters has been studied from the approach of target localization and kill. In addition, this study appears encouraging for classification purposes.[3] After the computer techniques for processing the data are found (Starlite is a strong candidate), these platforms could serve as receivers for ship-launched buoys also. These platforms might be able to determine buoy geometry more accurately with radar or optical measurement rather than sound delay information.

### 2.1.1.3 HYDROFOILS

Vulnerability: While more vulnerable than airborne craft, a torpedo poses very little threat if the craft is foilborne. Foil operation, however, requires approximately 25kts speed.

Classification Technique: Current configurations are considering a towed-body similar to VDS with higher operating frequencies ~30 kHz. While more traditional techniques might be useful with this type of sonar, the use of a towed-array and Starlite-techniques might provide the best classification capability. Naturally, the system must work at speeds above 25kts.

Comments: The designers of hydrofoil craft are considering the sonar problem at high speeds. Evidently, they feel that a towed-body can function at these speeds. In the sonobuoy case the significant motion effects were all due to the submarine. The trade-offs between the use of a single towed-body and a towed-array on the hydrofoil and sonar operation in general will also determine the eventual applicability of Starlite.

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3. S. S. Tobe, W. J. Kruse, "Effects of Active Sonobuoys and Towed Sonar Employment on the Attack Capability of a Single SH-3A Helicopter (U)," NADC-AW-6326, 2 December 1963 (CONFIDENTIAL).

2.1.1.4 STARLITE

Objective: Determine a means of estimating the utility of the STARLITE classification technique to Fleet operations; specifically, to develop some means of computing the coverage for classification with an AN/SQQ-23 (PAIR) destroyer equipped with STARLITE, comparing this to the detection coverage achieved by that sonar under Fleet operations, and to calculate distributions in both range and bearing for STARLITE Classification.

Results:[4]

a) Lateral range distributions were developed for STARLITE using PAIR parameters as a function of the single-ping probability of correct classification, relative speed between destroyer and submarine, sonar detection range, and torpedo runnout range.

b) An effective classification width corresponding to the sweep width for detection was calculated for each STARLITE lateral range distribution.

c) STARLITE classification coverage and the ratio of classification to detection coverage was computed for random convoy patrol tactics.

From this coverage information, it was shown that the overlap (in percent areas covered) of STARLITE coverage to detection coverage was over 80% for a 2.0 Kyds. detection range, over 85% for a 4.6 Kyds. detection range, and over 60% for 9.0 Kyds. detection range using random patrol tactics. Thus, the effectiveness of STARLITE against below-layer targets is very high since any targets detected in the first two cases (2.0 & 4.6 Kyd. detection range) would be within the effective classification area simply by a destroyer change of heading.

d) Probability density functions for the range and bearing at which a submarine is classified were developed. The density functions were developed both for the case where the submarine is on an intercept course with the PAIR ship and the case where the submarine's motion is unrestricted. The former case corresponds to a submarine trying to penetrate a convoy screen. The latter case will be useful in determining sonobouy effectiveness, since the submarine bearing, track angle and velocity with respect to the sonobouys is not constrained.

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4. D. G. Olson and J. E. Watring, "Preliminary Analysis of Possible STARLITE Development Programs," NUWC TN-48, January 1968 (CONFIDENTIAL).

The information gained from observing these density functions demonstrate STARLITE's strong and weak points in a tactical situation, the best convoy patrol deployment, and the most probable submarine tactics (assuming that the STARLITE technique is known to them).

## 2.1.2 MEDIUM EFFECTS

### 2.1.2.1 MULTIPATH PREDICTION

Kramer's recent work has convinced us that even in a short range situation 1,000 yards to 1,500 yards, multipaths can be expected. Based on a linear increase in temperature from 55°F at the surface to 70°F at 300 feet, with the submarine at 250 feet, a surface bounce echo was delayed by 2.9 msec with respect to the echo along the direct path for R = 1,000 yards. At R = 1,500 yards, the delay was 1.3 msec. These results suggest that classification systems based on the hypothesis of discrete specular target models must incorporate knowledge of the velocity gradient from bathythermograph or BT measurements in order to look for multipath effects separate from multiple reflections.

The PERT chart submitted to NAVSHIPS shows a main task of acoustic path studies. There is not a man available for this work at the present time and consequently, we will have to relay on Kramer for this until one becomes available. However, since the study in Par: 2.1.3.1 makes use of path structure, this work is essential. We are requiring an additional acoustician to work closely with us in FY '69 to support this vital area.

### 2.1.2.2 DETECTORS FOR ACTIVE SONAR

Objective: Extend the empirical performance curve analysis of the noise-weighted linear, simple linear, and polarity-coincidence correlator (initiated in FY '67), to include both CW and FM transmitted signals for the AN/SQQ-23 sonar.

2.1.2.2.1 RESULTS:

Generation of the theoretical and empirical performance curves for the CW case has been completed and is documented.[5] Results show that the noise-weighted linear correlator provides a significant gain in performance over the simple linear correlator only if the noise is void of reverberation. The simple linear correlator was found to provide a minimum gain of 4 db over the polarity-coincidence correlator independent of the composition of the noise background. From these results it was concluded that the simple linear correlator is the best suited of the three for detection of a known CW echo.

For the FM case, an ensemble of twenty-five linear up-sweep ($\Delta f = 312$, TW = 256) transmissions and their signal returns are being used to generate empirical performance curves. Progress has been somewhat slower than originally anticipated due to computation difficulties resulting from the length (over 800 milliseconds) of the FM transmitted signals.

2.1.2.2.2 PLANS FOR FY '69:

(a) Complete performance curve analysis of three detectors for AN/SQQ-23 FM transmitted signals.

(b) The following tasks will be initiated when the necessary data base becomes available:[6]

(1) Repeat FY '67 investigation of gaussian and stationary noise assumptions with ensembles of at least 200 CW and FM signal returns.

(2) Investigate the known signal and gaussian signal assumptions with respect to ensembles of 200 CW and FM transmitted signals as seen by the target and equally large ensembles of submarine echoes. These ensembles will also be used to investigate the transfer functions of the target and foreward and return path communication channels.

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5. J. L. Teeter, "Detectors for Active Sonar," NUWC TP-29, February 1968 (UNCLASSIFIED).
6. J. L. Teeter, "Data Requirements for Analysis of Active Sonar Detectors and the Process of Echo Generation," NUWC TN-41, December 1967 (UNCLASSIFIED).

(3) Extend the performance curve analysis for AN/SQQ-23 transmit signals to include the quadratic "noise in noise" correlator characterized by the matrix operator $R_N^{-1} - C_{S+N}^{-1}$, where $R_N$ is the noise autocorrelation matrix and $C_{S+N}$ is the signal plus noise covariance matrix.

(4) Analyze ensembles of 200 FM and CW echoes for a variety of aspect angles to investigate the relationship between target aspect angle and echo structure.

### 2.1.3 RECOGNITION SYSTEM

#### 2.1.3.1 OPTIMUM DETECTION AND ESTIMATION PRINCIPLES

This study is an attempt to unify the mathematics of detection and estimation theory within the context of active and passive sonar. Part I considers Deterministic Reflections/Radiations in Noise, and Part II deals with Random Reflections/Radiations in Nose. The work is intended to apply the concepts and methods of random processes, together with the a posteriori probability viewpoint of decision making, to the problem of optimum classification receiver design. Part I will establish the necessary and sufficient conditions for classification when the received signal implies a particular target class (deterministic) and is received over an additive guassian noise channel. Main emphasis will be placed on developing theoretical ROC curves for the hypothesized target classes as a function of S/N ratio (range). Specific examples will include the theoretical minimum probability of error for CW and FM waveforms, their relationship to the N-dimensional vector communication channel, and a comparative analysis of the two for classification purposes. Multivector channels (more than one receiver-bistatic) will be considered and the relationship of the channels to the theoretically derived ROC curves will be shown. The effects of multipaths which are resolvable and time-invariant will also be established theoretically.

Part II represents a considerable extension of Part I in terms of the mathematical difficulty. Here, the necessary and sufficient conditions for classification are derived when the reflected signal does not imply a particular target class, the received signal is itself a random process and hence, design is based on the effects of such random variables as: amplitude of reflection, time delays due to aspect, number

of reflections and other descriptors. Essentially, the ROC curves obtained theoretically in Part II can be compared to those in Part I, and the degradation in optimum performance assessed.

In all cases, the structure of the optimum receiver will be derived so that ASDACS can be used to simulate the design. Experimentally obtained results using real-world data for a given structure will be compared to the theoretically predicted results. All results, either good or bad, can be traced to the corresponding assumptions made in I and II and changed accordingly. Reports will be published on I and II.

The first major effort will be expended in the 1st quarter FY '69. This consists of a summer working group of six professionals whose backgrounds in detection, classification and tracking, coupled with their understanding of modern communication theory, will allow for an overview of the problems to be encountered in both I and II. A final report will be published on this effort.

### 2.1.3.2 OPTIMUM MODULATION TECHNIQUES

This problem is concerned with the Maximum a Posteriori (MAP) estimation of frequency modulation functions present in active and passive sonar signals. The MAP concept leads to optimum demodulator structures which are usually unrealizable. However, MAP estimation can be used to establish bounds on demodulator operation for comparison with suboptimum realizable demodulators. Analysis and experiments will be used to determine mean square estimation errors for the realizable demodulators by using a variety of sonar signals and noise. The experiments are to be carried out by using ASDACS.

The deterministic and statistical characteristics of instantaneous frequency variations of sonar signals will be investigated. (Instantaneous frequency variations are the frequency modulation functions to be estimated.) Analyses and experiments (using ASDACS) will also be carried out to determine the classes of sonar signals for which estimation of instantaneous frequency is desirable and useful. The first years' effort will determine modulation functions and demodulation schemes. Future data acquisition and analysis will be determined on the basis of results obtained here. Any hardware realization for investigation will also be determined. It is expected that particular sonar estimation problems will be more amenable to analysis once the background information is obtained in the first year.

### 2.1.3.3 SURVEY OF JOINT ACTIVE/PASSIVE RECOGNITION

The goal of this effort is to carry through the problem definition phase the development of an automatic or semi-automatic classification subsystem for the AN/SQQ-23 sonar. This would include attempting to answer as completely as possible the following representative but not inclusive list of questions:

1. How soon must a system of this type be completed to be useful to the SQQ-23 system? What is a reasonable time schedule?

2. What are the allowable tradeoffs between system size, cost, and completion time?

3. What work could be accomplished in-house and what should be contracted? What are the relevant costs and manpower requirements?

4. What are the technical and operational constraints imposed by the SQQ-23 system?

5. What should be the role of the operator in the classification process? What information must be presented to him?

6. What procedures might be used to evaluate potential target state vectors or clue values with regard to their separability properties for the classes of target and non-target echoes?

7. What are the data requirements for system development and evaluation?

8. What improvements over previous techniques such as TRESI system might be included within the allotted time for completion? Candidates for investigation under question 8 might include:

   (a) Integrating the tracking and classification process to more fully utilize multiple echo time sequence classification information.

   (b) More complete utilization of non-sonar inputs such as bathythermograph and bottom depth information.

   (c) Integration of passive and active classification functions.

   (d) Separate procedures for different target ranges and echo to noise ratios.

   (e) Implementation of STARLITE or other multistatic techniques.

## 2.1.4 TARGET MODELS

### 2.1.4.1 KINEMATICAL RELATIONSHIPS

#### 2.1.4.1.1 OBJECTIVE:

The effects of target motion on the reflection of a sonar signal and its processing receive attention in the signal analysis work. The magnitude of own ship's motion, target motion and the importance of different components of these motions depend on the characteristics of the targets and sensor platforms. Better techniques for computing all the terms of the general equations of motion are necessary to examine their effects on the sonar detection and classification problems.

The effects of certain terms depends on the exact sonar problem. In this respect, the study will supply inputs for signal processing with respect to correlator performance and some considerations of STARLITE performance. In this respect, the outputs of the study may be first applied to a particular problem. The equations of motion for a target with dimension (not a point reflector) became very complicated without simplifying assumptions. Therefore, the study output may not consist of one over-all report, but a series of solutions incorporated in other reports which deal with particular problem formulations. Further study, however, might permit a more comprehensive presentation.

After approximately six months of searching for a qualified new-hire to work in this area, we have been unable to find one. The work is vital and hence, we have decided to create a job-order for in-house work by the Advanced Control Systems Division for one man-year of effort.

Recent investigations in active sonar exploratory development have revealed a high degree of similarity between problems in communication theory and in modern control theory. Specifically, investigators state that a requirement exists for describing the reflected signal process (the plant's output) as a function of both the transmitted signal (the input control function) and the reflective characteristics and dynamics of the target vehicle (plant's state vector). The Advanced Control Systems Division is well qualified to provide assistance on this problem and will assure that the techniques of treating target motion and track are consistent with the best practices of modern control theory.

The problem requires derivation of the kinematical relationships between own ship and target when 3-dimensional motion occurs on transmit and receive for own-ship and reflection for the target vehicle. Briefly stated, the problem can be formulated as:

(i) Given: The surface ship transmits in the direction of the target which is at a range $R_g$ (range to target's center of gyration) and own-ship has angular rotation and both linear velocity and acceleration in 3-dimensions.

(ii) Find: Equations relating own-ship to the submarine's coordinate system.

(iii) Given: A submarine modeled as a long slender body of rotation, composed of a finite number of discrete specular reflectors.

(iv) Find: With respect to the submarine's coordinate system (center of gyration), a description of the vectorial velocities and accelerations of the $k^{th}$ reflector when there is vectorial angular rotation, linear velocity and linear acceleration.

(v) Given: The surface ship tows two hydrophones separated by a distance (X) and subject to motion at time of reception.

(vi) Find: The kinematical equations relating target and transmit motion to own-ship; a coordinate system for own-ship as a function of range, both receive bearing angles and time.

The results of this analysis can be used for detection, classification and tracking studies as they relate to motion, range and time. Simulation can be run on ASDACS to determine the effect of motion on the received waveform. For example, STARLITE can be simulated to determine its degradation in performance when high speed turns of the vehicle are occuring at time of reflection.

2.1.4.1.2 RESULTS:

A submarine target modeled as a line array of discrete reflectors and the sonar platform consisting of possible arrays of hydrophones are related by vector relations in a three-dimensional frame of reference. These kinematic relations have been derived in a general frame of reference external to both the target and sonar platform. The various mathematical variables in the derivation represent many angular

quantities that are used in sonar technology. The derivation can be made to include such effects as pitch, roll, yaw, surge, heave, and sway. In addition, the number of hydrophones or reflectors are also included with little difficulty. The frame can be shifted to any other point of interest with simple translation and rotation conversion technique. These equations were derived for use in sonar studies involving more complex sonar geometries.

For a point target, the translation and rotation vector variables have been used in calculating ambiguity functions for AN/SQQ-23 transmitted signals. The ambiguity function is used to measure the transmitted signals sensitivity in estimating target range and velocity. The velocity causes a doppler effect on the incident signal and reflects a time compressed image. The function is generated by cross-correlating the transmitted signal with a model of the reflected signal for a range of values for target angular velocity.

A model has been selected consisting of a fixed transmitter and a single reflector rotating at constant speed about a fixed center of rotation. (This is a simplification of a line array of discrete reflectors).

No energy losses are assumed and thus the amplitude of the reflected signal varies as the inverse of the square root of the (product of the) time compression factor ($\alpha$) with the time variable t.

The compression factor derived for this model is a continuous function of time. For a particular range ($\tau$) and angular velocity ($\omega$), the ambiguity function $\chi(\tau,\omega)$ is computed. Holding $\omega$ constant, $\chi$ is computed and plotted as a continous function of $\tau$.

The equations are coded in Fortran 63 in a programme for the CDC 1604 digital computer which is currently being debugged.

A plotting subroutine has been developed whereby the $\chi/\tau$ graphs are drawn in isometric projection for 7 discrete values of $\omega$ in order to plot the 3-dimensional surface $\chi(\tau,\omega)$.

Echo parameter highlites such as delay time $\tau$, pulse compression $\beta$, and the pulse attenuation $\alpha$ are determined by solving a minimization problem using nonlinear programming techniques. A target model is postulated as a line array of discrete reflectors. The echo signal will consist of the sum of replicas of the transmitted signal with all signals varied by target parameters; range, range rate and the reflective properties of each reflector. The echo highlite parameters are chosen as those that minimize a least squares function. With known noise variance, the estimates of the echo highlites are minimum variance estimates.

The method of Fletcher and Powell and the method of conjugate directions are nonlinear programming techniques that were employed to solve the mathematical programming problem. Results have been obtained only with simulated data.

Future plans include continued work on computing the ambiguity function for a target modeled as a line array of discrete reflectors. The present work performed with a CW reference pulse will be repeated with a linear FM pulse. The study will then be extended to include target linear velocity and possibly ownship's motion.

The kinematic equations derived in the first phase of the study will be utilized to obtain a mathematical representation of the sonar model suitable for use with techniques of sequential estimation. The study will then be concerned with practical aspects of detection, classification and tracking. Sequential estimation and techniques of echo highlite extraction will be integrated to improve these problems. Emphasis will be placed on treating the problem as a whole rather than in parts.

### 2.1.4.2 LINE TARGET REFLECTION ANALYSIS

An echo process is considered which is generated by a line segment reflector model where axis angle is a random variable with an assumed probability density. For each assumed density, calculation of the expected echo and autocorrelation functions is attempted for various sonar signals. Analytical results are obtained where possible and are supported by computer simulation. These calculations are the first step in the solution of the detection problem (i.e. detection of a random signal in noise).

The analytical results indicate, on the basis of expected echo calculations, that the line target looks very much like a point reflector (on the average). Autocorrelation functions for the echoes were not obtained analytically due to the nature of the target impulse response and choice of axis angle probability densities. Without autocorrelation function information available, the best detection procedure (assuming a Gaussian noise field) would be to cross-correlate the received signal with a weighted replica of the transmitted signal.

Further calculations of expected echoes should be carried out using other probability distributions of axis angle. These calculations should determine, for detection purposes, under what conditions the line reflector target can be approximated as a point target. Additionally, it

is expected that the line reflector model will later be combined with other models to form a more complete representation of a submarine.

An NUWC report on the line reflector model is currently being edited for final publication.

### 2.1.5 SIGNAL DESIGN

#### 2.1.5.1 SIGNAL REPRESENTATION

The report, "Linear Representation of Sonar Signals," soon to be published, deals with the problem of mapping sonar signals into vectors for further data processing in ASW active sonar systems. Many types of mappings can be used, and the special properties of each, affect the information content of a received signal in different ways. Thus the detection and classification performance of a sonar system may depend heavily upon the mapping employed.

The primary intent of the report is that of deepening the engineer's understanding of what linear representation is, rather than the solution of specific problems. Engineers have a tendency to think of representation in terms of Fourier series or time sampling and are often not aware of the many other possibilities which might prove more suitable in certain situations.

Specifically, the report contains (1) an exposition of the basic concepts behind linear signal representation, (2) the development of three basic types of linear representation mappings based on function space, normed space and Hilbert space structures for the signal ensemble, and (3) a listing of some historically developed basis functions which can be used to represent or approximate functions.

#### 2.1.5.2 ANALYSIS OF ACTIVE SONAR SIGNALS

A common way to perform analog studies of sonar data is to process, in a digital computer, digitized records of at-sea-recorded analog sonar signals. A short study is being conducted on the effects of sample rate and phase of the sampling waveform in performing correlation calculations.

A previous report* describes minimum sample rate requirements necessary for subsequent reconstruction of the analog signal. The purpose of the present study is to determine:

(1) If correlation may be performed at these minimum sample rates without first reconstructing the signal.

(2) The effects of correlating sets of samples which have different phase relationships with the original analog signal.

## 2.2 DATA COLLECTION

### 2.2.1 BACKGROUND

For the past several years, experimentors working on E1-11 have required various sets of sonar data to sustain their analytical efforts. In many cases the data available has not had the required specific characteristics, hence, analytical efforts have had to be confined to areas for which suitable data exists. The necessity for E1-11 experimenters to branch into more complex problems and broaden the scope of their detection and classification programs stimulated problem personnel to investigate the feasibility of establishing and maintaining a sonar data library at NUWC/SD.

The first step in establishing such a library was to conduct a survey of existing data. This survey was conducted and revealed that many sources of data were available. Contacts were made with people at NUWC/SD, NUWC/Pasadena, ASW School/SD, TRACOR, USN/USL, and DRL/Texas. A review of reports written by government contractors such as Raytheon, General Dynamics, General Electric, and Sperry Rand were also made. In every instance it became quite clear that the cataloging of data according to all the various characteristics is an enormous and complex task.

The task is complex because the documentation and instrumentation procedures used for the collection of data are as varied as the requirements of the experiments involved. In view of the man power available to E1-11, it was decided that such a comprehensive program was not feasible at this time. However, as a result of the data survey, it was discovered that very little of the existing data would be usable

* A NUWC Technical Note is expected to be published on this subject by 1 October 1968.

for future E1-11 experiments. Since it is clear that each experiment would, in most cases, necessitate at sea acquisition of the required sonar data, two methods for obtaining such data are to participate on a not-to-interfere basis, or schedule independent collection trips to meet the specific needs. The first of these has the advantage of making a particular sea trip more efficient in terms of ship and target time, but has the disadvantage of conflicting interests among the participants. The second is the most desirable, but is not always possible to implement because of the limited availability of Fleet services.

At this time, several types of data sets are required by E1-11 personnel. One of these requirements has been described in an NUWC Technical Note[7] Preliminary studies to determine the experimental parameters to be measured and the required instrumentation for such a collection trip have been completed.

### 2.2.2 FY 69 PLANS

In addition to a continuing effort to find suitable existing sonar data, E1-11 personnel will participate in a data collection trip being conducted in San Diego by DRL, first quarter FY '69. This operation will involve the USS Rogers (DD874) and the USS Camion. Our specific role in this operation has not been determined yet. However, it is certain that E1-11 personnel will act as observers and will install a small amount of equipment to insure that the data collection is convenient to use with the ASDACS system.

Recently, interest among analytical personnel in collecting one-way transmission data has arisen. Such medium effects as linear, time-varying, random impulse response measurements are areas of interest. It is known that a more complete understanding of the medium will help to eliminate some of the variables from the echo generation process. This collection effort, in terms of instrumentation, appears to be simpler than the typical controlled target exercise. Some of this collection can possibly be done on an underwater range such as AUTEC or BARSTUR. In cases where different or varied water conditions are desired, some type of portable buoy-hydrophone system with an RF-link could be used to collect the data. Such a device could be transported by the sonar platform and once put in the water, tracked by radar.

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7. J. L. Teeter, "Data Requirements for Analysis of Active Sonar Detectors and the Process of Echo Generation," NUWC TN-41, December 1967 (UNCLASSIFIED).

## 2.3 FACILITIES

### 2.3.1 ACTIVE SONAR DATA ANALYSIS AND CONVERSION SYSTEM (ASDACS)

#### 2.3.1.1 OBJECTIVE

The objective of the sonar detection and classification analysis problem is the development of advanced signal processing techniques and the testing of these techniques against "real world" sonar data. To meet this objective, a highly flexible and integrated high speed computer and conversion system was required.

#### 2.3.1.2 SYSTEM DESCRIPTION

ASDACS will be utilized to play back taped sonar data, condition the data, digitize it, and do real-time processing for detection and classification studies. Analog tapes are or will be available from a variety of data collection projects. The programmable analog and digital patch boards will make the system flexible and adaptable to the changing needs for processing and analysis of signals from a variety of sonar systems. A great deal of general purpose capability is also inherent in the system since the digital processing section contains a general purpose high-speed computer having all the necessary software and peripheral equipment.

The system is divided into four sections which provide the functions of signal conditioning, analog and digital interfacing, control and display, and digital processing. Figure 1 is a block diagram showing the general flow of information within and between these functional sections. Data enters the input analog patch panel from an analog tape unit. The data is routed through proper conditioners to either the output analog patch panel or to the digital patch panel. The analog signals are routed to the visual and aural monitor units and to the analog interface where they are digitized and sent to the central processor. The digital and discrete timing signals are routed to the desired inputs of the digital input/output and control interface and on to the central processor. The central processor in turn sends digital data and control pulses back through the digital and analog interfaces for display and control

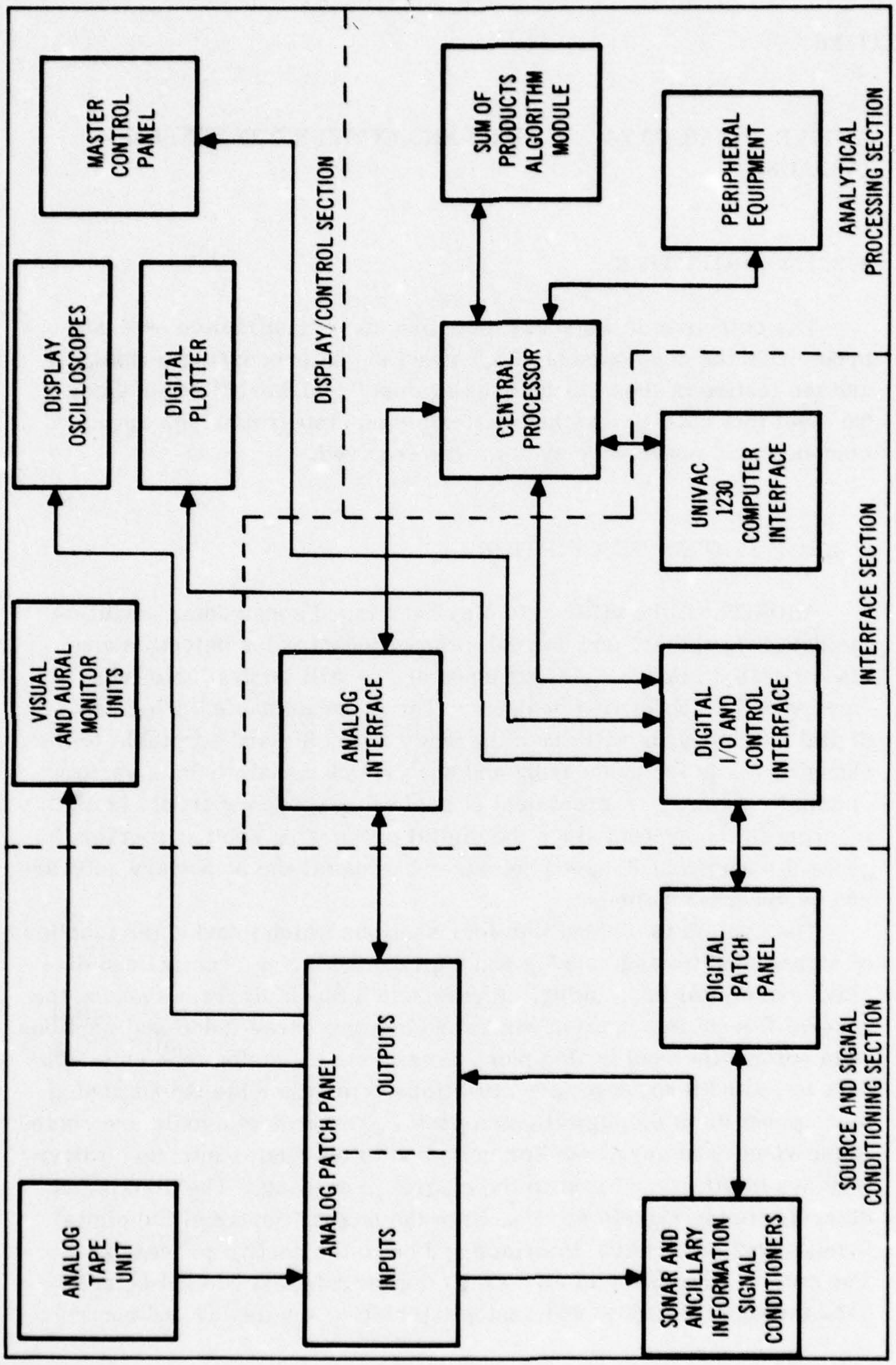


Figure 1. ASDACS block diagram

purposes. It communicates with peripheral digital equipment for input and output of data. It also communicates with the sum of products algorithm module (SPAM) used for real-time correlation and convolution calculations.

Figure 2 is a picture of digital processor and peripheral devices. The 1700 computer main frame and console is shown on the right. Between the computer and the two digital mag tape units are the SPAM and 1706 Buffered Data Channel modules. The disk pack and driver are to the left of the tape units. The two units on the left contain standard and special interface hardware such as the D/A converters, 1230 interface, etc. On the top and on the left of these units is the delogger. The Calcomp plotter on top of the control console is shown on extreme aft forefront.

Figure 3 shows the 1700 computer again along with the teletypewriter (includes slow speed paper tape reader and punch). To the right of the teletype is the Ampex FR 1800 analog tape recorder/ playback unit. Again a portion of the central console is shown on the right.

Figure 4 shows the operator control console for the ASDACS system. The equipments on top of the console from left to right are:

Left section (3 panels): Analog patch panel; 16 buffer amplifiers (top), 5 adjustable interrupts (middle) and digital ships information translator (bottom); time code translator computer interface (top), tape search unit (top middle), time code translator (bottom middle), tape search and translator signal controls (bottom);

Center Section (2 panels): Two envelope threshold detector units (top), Type 565 Dual Beam Oscilloscope (center), 7 Calico monitor scopes (bottom); 2 envelope threshold detector units (top), 2 identical Type 564 storage scope (center and bottom);

Right Section (2 panels and plotter): 1587 control panel with digital display; digital patch panel (top), and spare space (bottom); Calcomp 565 Plotter.

In figure 4, the lower panels on the left side contain the Sample and Hold unit, ADC/Multiplexer, 5 Kronhite filters, and power supply for threshold detector. The lower panels on the right contain the 2 Stereo Amplifiers, 2 power supplies for adjustible interrupts and zero axis crossing detector, and spare storage.

A comprehensive report providing detailed information concerning the equipment description and operational capabilities will be written

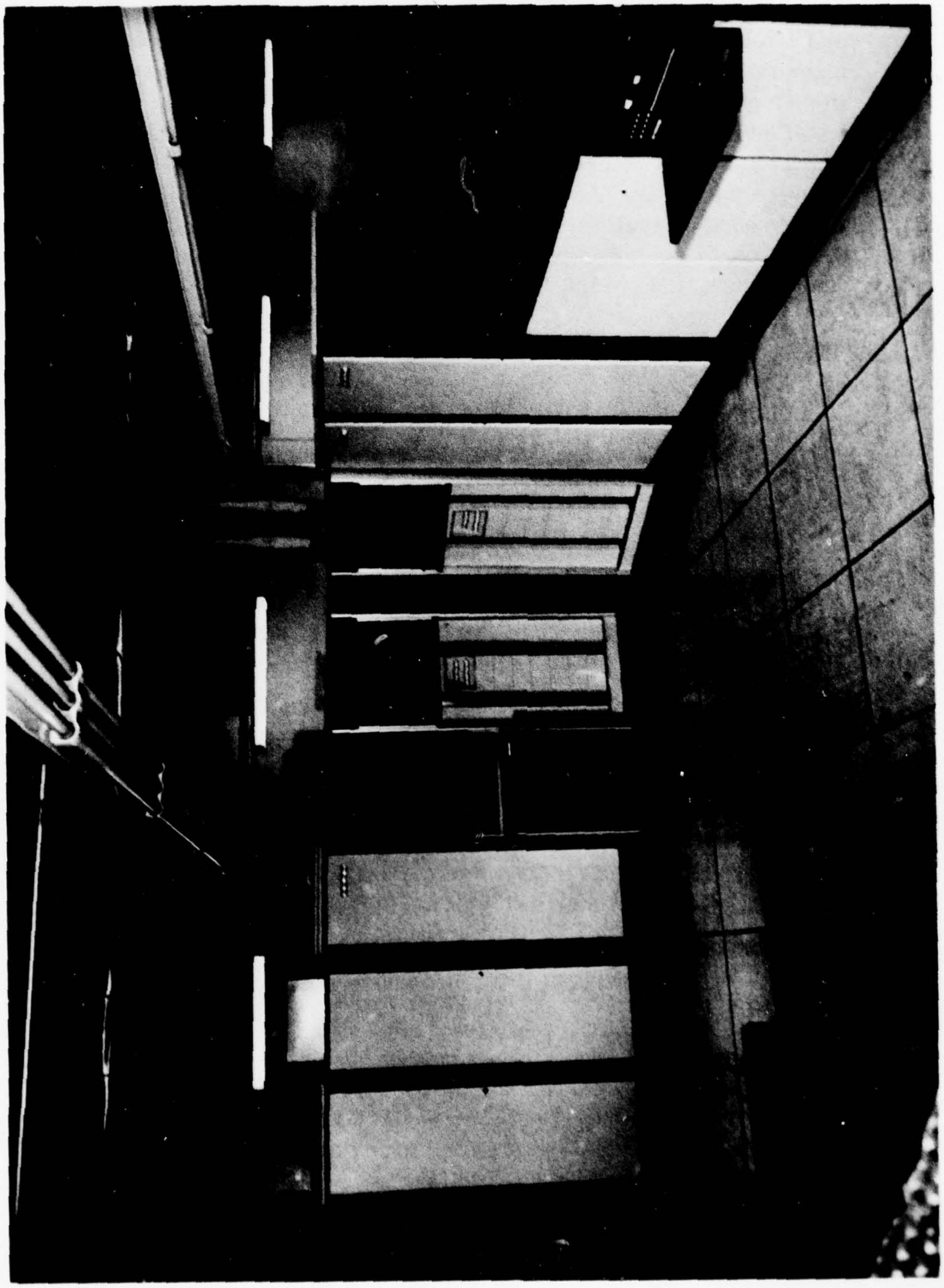

Figure 2. ASDACS Disk File, Tape Units, Interface Equipment, SPAM and Computer

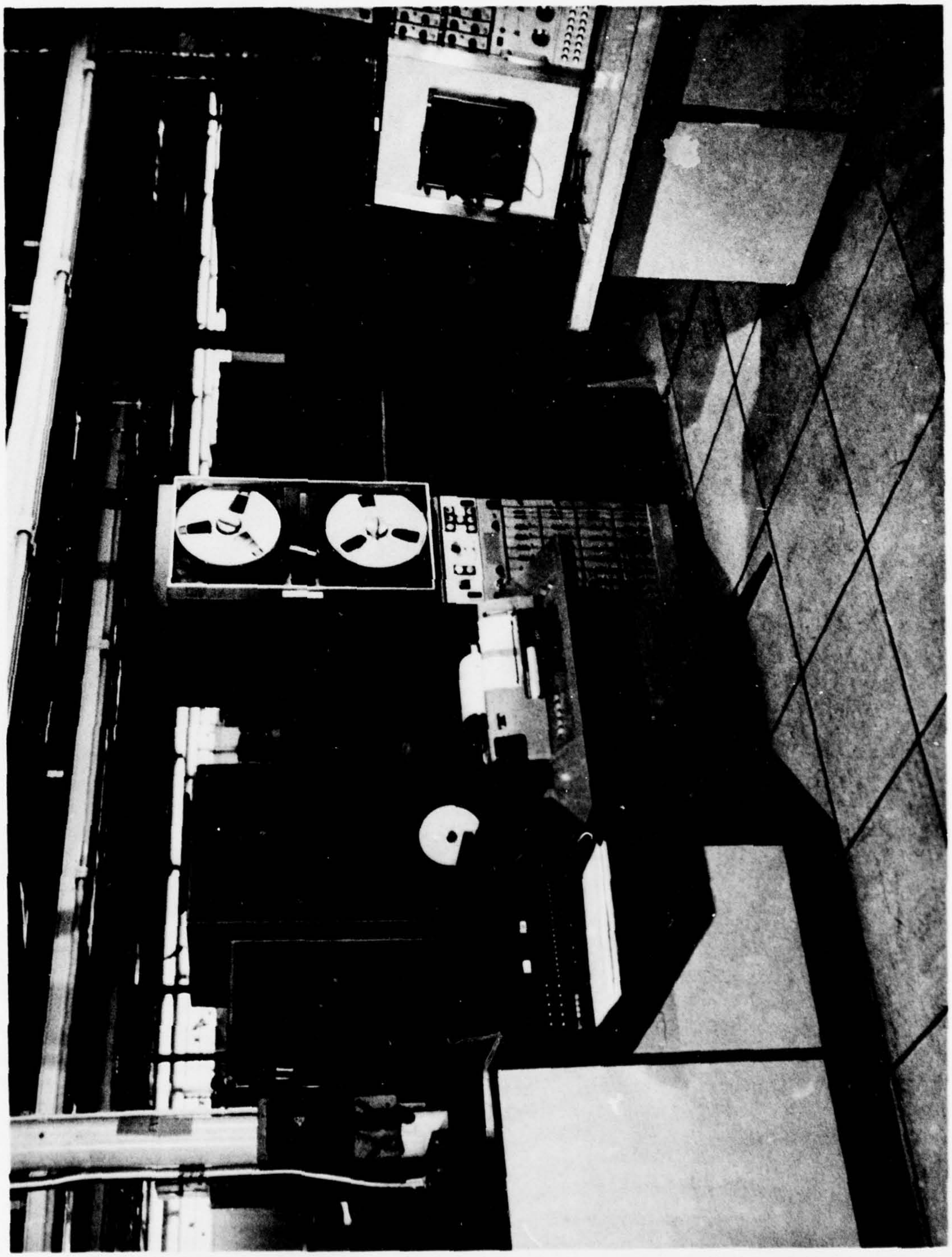

Figure 3. ASDACS Computer Console, Teletype and Analog Tape Unit

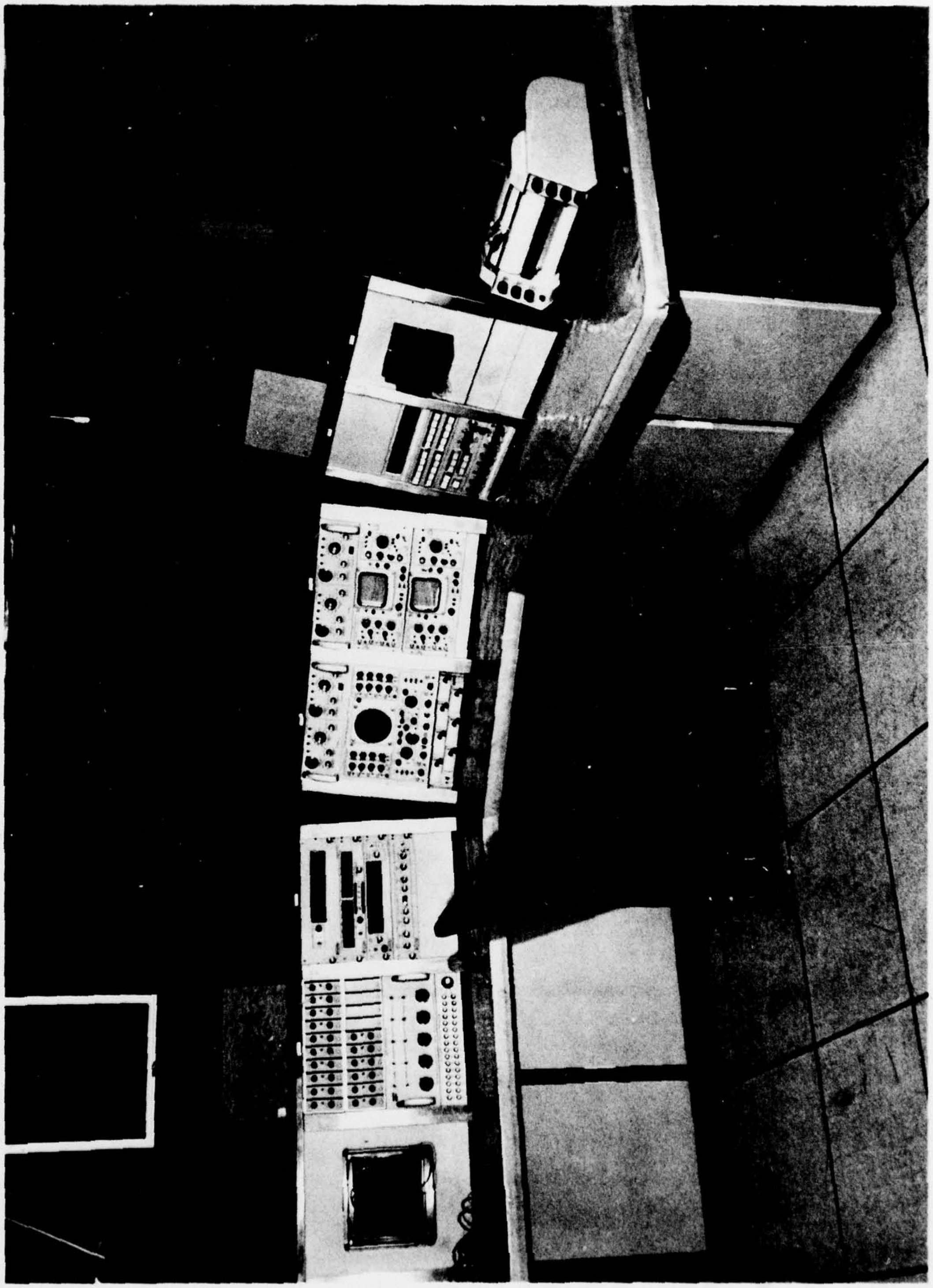

Figure 4. ASDACS Central Control and Display Console

and circulated after the system has been delivered and full operational status is achieved.

#### 2.3.1.3 SCHEDULE AND CONTRACT STATUS

The present schedule (best estimate) indicates that the final draft of the acceptance test specification will be received during the week of 22 July. Individual component tests are scheduled to begin at the same time with integrated hardware tests beginning the week of 29 July. It is expected that two to three weeks will be necessary to complete these tests and the final in plant performance capabilities envolving both hardware and software will not be demonstrated until the end of August. Allowing two weeks for installation and checkout and another three weeks for a rerun of the acceptance tests on site, it is expected that the system will go into useful operation around the end of September.

If this schedule comes to pass, it will reflect a one and one-half month late delivery on the part of the contractor as defined in *the contract. it will be the prerogative of the NPOLA to attempt* to get financial consideration for this contractual deficiency.

The largest single reason for the late delivery has been the discontinuity of contractor personnel assigned to the project. Several changes in programmers and the temporary reassignment (3-1/2 weeks) and recent illness (4 weeks) of the project manager resulted in a slow down in the software development and documentation. More emphasis has now been placed in these areas and the above schedule appears to be realistic.

#### 2.3.1.4 PROCUREMENTS/CHANGE ORDERS

Additional equipments and supplies were added to increase the utility, capability and flexibility of the ASDACS system. A list of these are:

a) Desk Console for conditioning, control and display equipment (see figure 4)

b) Tape Search Control Unit to be used for automatically locating a desired section on an analog tape as specified by a particular time code.

c) One (1) ADSE 8001 Digital Tape Unit – Two tapes units are very desirable in any computer system; one can be used for input and the other for output.

d) An additional 8192 words of core memory – the system now has 24,576 words of memory; since the 16 bit word size + parity bit and protect bit requires a lot of relative and indirect addressing, the larger memory size increases the capability of the computer.

e) Five (5) additional Model 850 Disk Packs to provide more flexibility by providing separate disks for different operations.

f) A Calcomp Plot routine for 1700 computer which provides immediate utility of the 565 plotter without any in-house programming effort.

g) A 1557D, 8 digit decimal display to replace the 1557C, 6 digit decimal display originally selected for the system. It increases the range of information that can be displayed.

h) A Soroban Card Reader and Interface to provide a primary source of input information at a much faster rate (1100 cards/min) than the slow speed paper tape reader on the teletype unit. It eliminates the need for off-line card to tape for input. The delivery on the card reader will be 45-60 days from July 1, 1968. The Interface between ASDACS and and Soroban Card reader will be designed and built by a small local firm, Digital Scientific Corp. Delivery of the Interface will be within 30 days after delivery of the card reader. NUWC will provide the necessary software.

### 2.3.1.5 TRAINING

Control Data (La Jolla Div.) offers regular Courses for their customers. Additional courses are offered by the local marketing and sales office. Still others are available at any Control Data Institute School (Los Angeles) for a fee. The contract with CDC specifies that they provide training on the ASDACS system.

### 2.3.1.5.1 COMPLETED TRAINING

The following list contains short descriptions of those courses pertinent to ASDACS and the 1700 computer. For each, the course length and number of E1-11 personnel attending the course are indicated.

6 a. 1700 Basic Computer – One (1) day, six (6) people

Introduction to the 1700 CPU I/O Control, instructions reperetoire, memory addressing schemes and sequence of operations.

40 b. 1500 Series Equipment – Ten (10) days, four (4) people

Instructions on 1500 I/O, instruction formats, logic, physical layout, cables and panels.

24 c. 1700 Assembler – Three (3) days, eight (8) people

Instruction in the symbolic assembler language used with the 1700 computer.

24 d. 1700 FORTRAN – Three (3) days, eight (8) people

Instruction in the use of the Fortran language.

50 e. 1700 Standard Software – Ten (10) days, five (5) people

An introduction to the use of the E006 operating system including monitors, drivers, message processor, job processors, Fortran interface and all background programs.

5 f. Control Data Corp Computers – Five (5) days, one (1) person

Introduction to Control Data Computers. A prequisite course for the 1700 Main Frame course. It outlines the CDC computer philosophy and describes logic functions and symbology.

? g. ASDACS familiarization – Six (6) people

Practical programming of ASDAC system using CDC in-house facilities. This training was not a formal course but, consisted of compiling and assembling system and analytical programs. It provided experience necessary for the efficient execution of the final acceptance tests.

2.3.1.5.2 FUTURE FY '69 TRAINING

Tentatively, a work-shop course is planned that will provide D606 personnel with a minimal background in the operation and analytic functions of ASDACS. The length of the course will be three (3) weeks and will deal primarily with the development of systems and analytical programs.

An additional training sequence is planned that will provide a technician with the background necessary to perform maintenance and support functions for the ASDACS system. The following list, along with a brief description, outlines the training sequence.

15 a. CDC 1700 main frame – Five (5) weeks

Instruction on the complete 1700 CPU with emphasis placed on the logic functions of control, memory, arithmetic, and I/O timing.

5 b. 8001/8000 Digital Magnetic Tape Recorders – One (1) week

Provides instruction in the logic and servo control functions of a high speed magnetic tape system.

10 c. 853/1738 Disk Drive and Controlles – Two (2) weeks

Provides instruction in the logic and servo control functions as well as disk addressing.

5 d. TTY 35, Teletype – One (1) week

Provides Instruction in theory of operation of the ASDACS on line typewriter.

10 e. CDC 1500 Series Equipment – Two (2) weeks

45 M/D Same as described in 2.3.1.5.1(b).

2 M/M

2.3.1.6 MAINTENANCE

Mr. Edward F. Tynen has been recently hired to perform maintenance and support functions of the ASDACS system. He will also participate in data collection experiments by performing functions such as instrument calibration and installation, logic design of digital interfaces, and aid in collection of data at sea.

Mr. Tynen has a strong background in analog equipments having worked in the instrument calibration laboratory of NELC. More recently he has gained a background in digital systems having worked in the Applied Systems Development and Evaluation Center (ASDEC) of NELC. In addition to this recent experience, Mr. Tynen has had extensive experience in military electronics and personnel instruction. While serving in the U.S. Navy he attained the rank of Chief Warrant Officer/Electronics (W-3) and since his separation has worked as a field engineer for both General Electric and Philco. Currently, Mr.

Tynen is attending the Control Data Institute. The course of instruction is the beginning phase of the maintenance training sequence of FY '69.

### 2.3.2 HETERODYNE UNITS

As a result of the heterodyne design study[8], a Four (4) channel Heterodyne Unit has been designed and constructed by D606 personnel for inclusion in the ADSACS system. It has also been decided to purchase commercial filters to use with the unit.

The circuit developed has a carrier rejection better than 45 db at a signal frequency of 20 kHz and better than 50 db for signals with frequencies less than 10 kHz. With proper filtering, the carrier rejection is better than 70 db below the level of the desired frequencies.

During the final design study, the tasks indicated in the last letter report were explored and evaluated. It was found that due to interaction between the two halves of the circuit, no significant gain in performance was achievable by the use of F. E. T. switches. Weill's proposed method for cancellation of the third harmonic was tested and found to be effective; however, for the frequency range of interest, the relaxation of filter requirements was so slight that it was decided not to use this method.

After the final circuit had been developed, the filter requirements were determined and a literary survey was made of existing commercial units. A technical evaluation of the Dytromics and Krohn-Hite filters was made to check their comformance with necessary requirements.

Jobs still outstanding before completion of the task are purchase of the necessary filters and the writing of the technical manual.

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8. G. M. Howard, "A balanced Switching Audio Modulator with High Carrier Rejection," NUWC TN-32, September 1967 (UNCLASSIFIED).

### 2.3.3 INSTRUMENTATION

#### 2.3.3.1 AMPEX FR-1800L ANALOG INSTRUMENTATION RECORDER/REPRODUCER

This unit was delivered in early March for integration into the ASDACS system. The major features of the basic transport are:

a. Pneumatic tape handling system with no pinch rollers.

b. Biderectional, seven-speed operation for flexibility.

c. Seven- or fourteen-channel (plus voice track) capability.

d. Fast response time base servo which accepts 60 Hz-FM, IRIG 17 kHz, and standard FR-1800L servo signals.

The major features of the record/reproduce assembly are:

a. Fourteen channel FM record/reproduce capability.

b. Seven channel DIRECT record/reproduce capability.

c. Electrically switchable electronics.

d. DIRECT channel specifications: at 60 ips, bandwidth 300 Hz to 300 kHz (±3 db) at 35 db signal-to-voice ratio.

e. FM channel specifications: at 60 ips, bandwidth DC to 20 kHz (±1 db) at 50 db signal-to-voice ratio and 1.2% harmonic distortion.

#### 2.3.3.2 GENERAL RADIO 1910-A RECORDING

Wave Analyzer – delivered in late March this instrument is used to analyze the frequency components present in complex electrical signals. With the built-in strip chart recorder, the analyzer can also be used to automatically plot frequency response curves of devices under test. The analyzer has a dynamic range of 80 db, a frequency range of 20 Hz to 54 kHz and switch-selectable bandwidths of 3, 10 and 50 Hz.

#### 2.3.3.3 HEWLETT PACKARD 3722A NOISE GFNERATOR

Delivered in early April, this device generates pseudorandom or random binary sequences. These sequences can be outputted directly or they can be filtered to obtain a gaussian probability distribution of amplitudes. The noise generator will be used in simulation studies where it is undesirable to use computer time for noise generation. The generator can also be used to obtain frequency response and cross-modulation products of a device under test.

## 2.4 CONSULTATION AND AUXILIARY TASKS

### 2.4.1 NAVSHIPS CLASSIFICATION PANEL

During FY '68, no extensive contractor survey trips took place, NUWC panel members Stradling and Ball did provide reports as required on proposals submitted and work in progress. The following lists the contribution by the panel during this 2nd half reporting period:

(a) 4 January 1968; Comment on Antisubmarine Classification Manual (U), NWIP 24-1(A), CONF.

(b) 14 March 1968; Comments on "Interim Reports; Analysis of ASW Contact Classification Procedures," Dunlap and Associates Report, BSD No. 67-439, 28 November 1967 (CONFIDENTIAL)

(c) 3-5 April 1968; NAVSHIPS Active Sonar Classification Advisory Panel Meeting in Washington, D.C.

(d) 3 May 1968; Comments on Bendix Proposal No. 90-544-1, of 19 January 1968.

(e) 8 May 1968; Comments on Tracor Proposal No. 67-154, of 7 March 1968.

### 2.4.2 PRESENTATIONS

Presented at NUWC SINEXCO meeting of 25 May 1968:

(a) "Detectors for Active Sonar," by J. L. Teeter.

(b) "Summary of Active Sonar Classification Research," by C. S. Stradling.

### 2.4.3 ACADEMIC TRAINING

L. P. Mulcahy completed two year Master's program in communication Theory at Purdue University, June 1968. Examples of courses taken are, Statistical Communication Theory, Signal Analysis, Linear System Analysis, Digital Detection Theory, Information Processing, and Analog Demodulation.

J. L. Teeter completed first year of part-time doctoral program at U.C.S.D. Course work in Random Process Theory and mathematics related to communication and Detection Theory.

C. S. Stradling, T. F. Ball, and G. A. Turton completed one year course in Modern Control Theory sponsored by NUWC and presented by BB&N.

# 3. ADMINISTRATIVE

## 3.1 PERSONNEL

The following personnel are associated with SF-11-121-100/8132.

Ball, T. F. GS-12 (D606)
Bolks, D. J. GS-11 (D606)
Dejka, W. J. GS-13 (NELC-S360)
Gechter, R. G. (CAI Contract)
Howard, G. M. GS-04 (D606/CO-OP Student)
Jackson, E. G. GS-12 (D606)
Mulcahy, L. P. GS-12 (D606)
Olson, D. G. GS-12 (D606/Terminated)
Schumacher, G. P. GS-13 (D606)
Stradling, C. S. GS-13 (D606)
Teeter, J. L. GS-11 (D606)

Turton, G. A. GS-11 (D606)
Tynen, F. F. GS-11 (D606)
Watring, J. E. (CAI Contract)
Weill, L. R. GS-12 (D606/Summer Hire)

## 3.2 FUTURE PLANS

### 3.2.1 DURING FY '69

(a) Complete performance curve analysis of three detectors for AN/SQQ-23 transmit signals.

(b) Initiate (if data is available) investigation of gaussian and stationary noise and known and gaussian signal assumptions using transmit signal and signal return ensembles of 200 members.

(c) Initiate (if data available) performance curve analysis of quadratic "noise in noise" correlator $(R_N^{-1} - C_{S+N}^{-1})$ for AN/SQQ-23 *transmit signals.*

(d) Study capabilities and limitations in the MAP estimation of instantaneous frequency of sonar signals.

(e) Investigate the effectiveness of STARLITE using various sunobuoy arrangements.

(f) Complete analysis to predict the a-priori performance of STARLITE systems and methods of use.

(g) Suggest methods of determining operational effectiveness once data becomes available.

(h) Complete problem definition study for AN/SQQ-23 Classification System.

(i) Calculate ambiguity function for rotation and linear velocity using CW and FM signals.

(j) Report on summer study of optimum detection and estimation principles.

(k) Participate in sea-tests for gathering echo ensembles.

(l) Complete Heterodyne report.

(m) Simulate experiments on receiver structures with ASDACS.

### 3.2.2 FY '70

(a) Report on results of ASDACS experiments; consider application to future sonar systems.

(b) Consider feasibility of joint classification and detection system using PAIR receiver.

(c) Development of joint active and passive classification systems; simulate on ASDACS.

(d) Examine theory of tracking as relates to detection and classification.

## 3.3 FINANCIAL

### 3.3.1 SUMMARY

| | FY 68 | FY+1 69 | FY+2 70 | 71 | 72 |
|---|---|---|---|---|---|
| Investigative Man-Years | 8.0[1] | 8.5[2] | 11 | | |
| Total Direct Labor Man-Years | 8.5 | 9.0 | 11.5 | 12 | 13 |
| Total Labor and Overhead $ | 190 K | 211 K | 285 K | | |
| Normal Material and Travel $ | 30 K | 34 K | 35 K | | |
| Major Procurement $ | 304 K | 105 K | 134 K | | |
| Planning Estimate $ | 524 K | 350 K | 454 K | 477 | 492 |
| *Additional Funds Required $ | -0- K | -0- K | | | |

1. Co-op student on board is charged under major procurement.
2. Includes predicted replacements for Olson and Weill.

### 3.3.2 MAJOR PROCUREMENTS

| FY | Item | Cost and Quarter to be Committed | | | |
|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th |
| 68 | Programming Services and Co-op | 48K | | | |
| | ASDACS Work Change Orders | | | 51K | |
| | ASDACS Contract | 189 | | | |
| | ASDACS Work Change Order | | | | 5K |
| | Summer Hire | | | | 5.0K |
| | AMPEX 1/2" Head Assembly/Time Code Generator | | | | 6.0K |
| | FY 68 Total 304 | 237 | | 51K | 16.0K |
| 69 | Programming Services | 20 | 20 | | 10 |
| | NELC Analytic Services | 25 | | | |
| | ASDACS Maintenance and Spare Parts | | 30 | | |
| | FY 69 Total 105 | 45 | 50 | | 10 |
| 70 | Programming Services | 20 | 20 | 15 | 20 |
| | Disk File Rental | 9 | | | |
| | ASDACS Maintenance | | 25 | | |
| | Test Instrumentation | | | 25 | |
| | FY 70 Total 134K | 29 | 45 | 40 | 20 |

### 3.4 ACTIVE CONTRACTS

Control Data Corporation, La Jolla Division, 4455 Miramar Road, La Jolla, California 92037, N00123-68-C-0299 for an Active Sonar Data Analysis and Conversion System (ASDACS).

Mr. D. G. Olson, 525 Stratford Place, Chicago Illinois; P60530/D6060-D0031 for a classified report on target classification.

3.5 TECHNICAL REPORTS ISSUED: 1/1/68 - 7/1/68

D. G. Olson and J. E. Watring, "Preliminary Analysis of Possible STARLITE Development Program" (U), NUWC-TN 48, January 1968. CONFIDENTIAL.

D. G. Olson, "Representing Sonar Signals as Real and Complex Function", NUWC-TN 67, February 1968.

C. S. Stradling, "Two-Channel Passive Signal Detection", NUWC-TN 80, March 1968.

J. L. Teeter, "Analysis of Detectors for Active Sonar", NUWC-TP 29, April 1968.